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(54) Capacitive distance sensor, particularly for acquiring fingerprints

(57) The distance sensor has a capacitive element (33, 34) in turn having a first armature (23) which is positioned facing a second armature (18) whose distance is to be measured. In the case of fingerprinting, the second armature is defined directly by the skin surface of the finger being printed. The sensor comprises an inverting amplifier (13), between the input and output of which the capacitive element (33, 34) is connected to form a negative feedback branch. By supplying an electric charge step to the input of the inverting amplifier, a voltage step directly proportional to the distance being measured is obtained at the output.

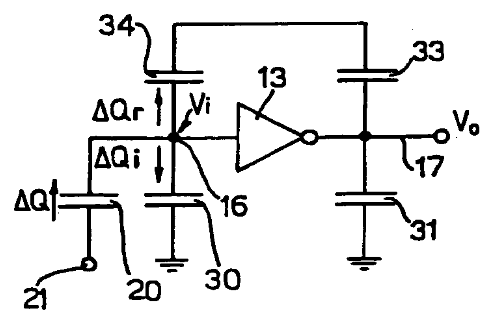

Fig. 3

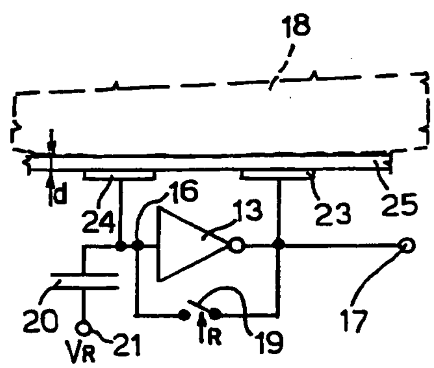

Fig. 2

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Description

The present invention relates to a capacitive distance sensor, in particular, a small-distance (micrometric to millimetric) sensor.

Small-distance sensors are used, among other things, as pressure, proximity, roughness, mechanical stress and acceleration sensors, for example, in integrated microphony and for acquiring fingerprints.

For fingerprint acquisition in particular (to which reference is made herein purely by way of example of a preferred application of the present invention), known sensors include various types, for example: optical, piezoelectric, variable-conductance, thermal, ultrasonic and capacitive, the most promising of which in terms of precision, size, production and cost are capacitive sensors.

Capacitive sensors are based on the principle that the capacitance between two armatures is inversely proportional to the distance between them, so that, using the contacting dermal tissue itself as the second armature of the sensor capacitor, and by determining the capacitance, it is possible to locate the ridges and grooves of the fingerprint. This is the principle used in US-A-5,325,442 to Knapp, which relates to a sensor comprising an array of elementary cells, each comprising a sensitive electrode and an electronic switching device. The electrode is coated with dielectric material, such as passivation oxide or a polymer compound, onto which the epidermis is placed. When a cell is selected, a predetermined variation in potential is applied to the electrode to induce at the terminals an appropriate variation in charge, the extent of which depends on the capacitance associated with the electrode, and which is read by amplifying elements connected to the output of the device. To improve efficiency, the above patent suggests a surface grid connected to a reference potential to appropriately bias the skin tissue.

In the above known capacitive sensor, the capacitance between the armatures of a capacitor varies in inverse proportion to the distance between the armatures, which therefore poses the problem of normalizing the resulting data. In particular, if the capacitance being measured is very small, as in the application in question, serious difficulty is encountered in detecting the charge and discriminating between the various intermediate charge levels corresponding to different grey levels of the image to be generated in the presence of a low signal/noise ratio.

It is an object of the present invention to provide a sensor designed to overcome the drawbacks typically associated with known technology.

According to the present invention, there is provided a capacitive distance sensor, as claimed in Claim 1.

In practice, according to the present invention, the detecting capacitor, the distance between the armatures of which is to be determined, is placed in a negative feedback loop, thus inverting between the denominator and the numerator the dependance of the output voltage on the distance between the armatures.

A preferred, non-limiting embodiment of the present invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows a sensor device for acquiring fingerprints;
Figure 2 shows a detail of a cell of the Figure 1 device;
Figure 3 shows the electric equivalent of the Figure 2 cell.

Figure 1 shows a sensor device 1, preferably embodied in an integrated chip, comprising a number of cells 2 arranged to form an array 3 and each constituting an elementary sensor.

Device 1 also comprises a horizontal scanning stage 5 and a vertical scanning stage 6 for enabling one cell 2 at a time according to a predetermined scanning pattern. Preferably, to read the cells, stages 5, 6 enable the outputs of the cells sequentially, and comprise shift registers or decoders.

Device 1 also comprises a supply and logic stage 7, which supplies the components of the device (including cells 2), feeds the necessary reference voltages, and controls the sequence of steps provided for (as explained in detail later on). In particular, Figure 1 shows a voltage source 12 for generating a reference voltage variation ΔV_R; a buffer 8 is connected to the outputs of all the cells 2, and supplies, at output 10 of the device, the signal present at the output of the cell 2 enabled by scanning stages 5, 6.

As shown in Figure 2, each cell 2 comprises a low-power inverting amplifier 13 of gain A, in turn presenting an input 16 at input voltage V_i, and an output 17 at output voltage V_o and defining the output of cell 2; two armatures 23, 24 of equal area, which are positioned facing the skin surface 18 of the finger being printed; a reset switch 19 connected between the input 16 and output 17 of inverting amplifier 13; and an input capacitor 20 connected between input 21 of cell 2 and input 16 of inverting amplifier 13.

More specifically, armatures 23 and 24 are respectively connected to output 17 and input 16 of inverting amplifier 13, and are covered with a dielectric layer 25 covering the face of integrated device 1 at array 3 of cells 2. In use, therefore, skin surface 18 forms a second armature facing armatures 23, 24, and defining with them a pair of series capacitors feedback connected between input 16 and output 17 of inverting amplifier 13, so that a contact grid is not required to bias the skin surface at constant voltage.

Switch 19 is a controlled switch formed using any known technology (e.g. a MOS switch) and receives a control sig-

nal R from supply and logic stage 7. Input 21 of the cell is also connected to supply and logic stage 7 to receive a voltage signal ΔV_R as explained below.

To acquire fingerprints, skin surface 18 is placed on the surface of integrated device 1, at array 3, to complete the pairs of capacitors forming the feedback loops of amplifiers 13 of all the cells. At the start of the measurement, switches 19 of all the cells are closed, and the voltage level at inputs 21 is constant, so that the input voltage V_i of all the cells 2 is brought to the same potential V_o as the output, between the supply and ground at a high-gain point of inverting amplifier 13.

Subsequently, supply and logic stage 7 opens all the switches 19 in parallel, and supplies all the inputs 21 with a voltage step ΔV_R, so that a charge variation $\Delta Q = C_i{}^*\Delta V_R$ (where C_i is the capacitance of input capacitor 20) is induced at the terminals of input capacitors 20 to permit a reading, as explained below, of the local distance d between armatures 23, 24 and skin surface 18 facing them. Obviously, local distance d varies according to whether the point being measured corresponds to a groove, a ridge or a point between the two.

Scanning stages 5, 6 then sequentially enable the reading of cells 2, so that the voltage signal at output 10 of buffer 8 is supplied to a system for representing the distance, in known manner, by means of grey levels, and so providing a three-dimensional display of the skin surface.

The way in which local distance d between armatures 23, 24 of each cell 2 and the armature formed by skin surface 18 is detected will now be described with reference to the equivalent electric diagram in Figure 3.

Figure 3 shows the equivalent input capacitance 30 and output capacitance 31 of inverting amplifier 13; the charge flow direction (indicated by the arrows) corresponding to the voltage variations at the armatures; and the capacitors 33, 34 formed by armatures 23, 24 and skin surface 18.

Assuming C_l is the equivalent input capacitance of inverting amplifier 13 (capacitance of capacitor 30); C_r is the total capacitance of series capacitors 33 and 34; A is the gain of inverting amplifier 13; ΔQ is the charge variation induced in capacitor 30 by voltage step ΔV_R; ΔQ_i is the charge variation stored in equivalent input capacitance 30 as a result of step ΔV_R; ΔQ_r is the charge variation in the feedback branch formed by the series connection of capacitors 33, 34; ΔV_i is the voltage step at input 16 of inverting amplifier 13; ΔV_o is the corresponding voltage variation at output 17 (equal to -A ΔV_i); S is the surface of each armature 23, 24 of capacitors 33, 34; ε_o is the electric constant (seeing as, in the application in question, the average distance between the skin and insulating layer 25 - typically 60 μm at the grooves - is greater than the thickness of layer 25 - typically 2 μm); and d is the local distance between armatures 23, 24 and skin surface 18 (approximately the same for both armatures 23, 24, in view of the very small size of cells 2 - typically about 45 μm); then total feedback capacitance C_r is given by the following equation:

$$C_r = \frac{S\varepsilon_0}{2d} \tag{1}$$

Moreover:

$$\Delta Q = \Delta Q_l + \Delta Q_r = C_l\,\Delta V_l + C_r\,(\Delta V_l - \Delta V_o) =$$
$$= -\frac{\Delta V_o}{A}(C_1 + C_r) - \Delta V_o C_r$$

so that:

$$\Delta V_o = -\frac{\Delta Q}{\frac{C_1}{A} + \left(1 + \frac{1}{A}\right)C_r} \tag{2}$$

Substituting (1) in (2) gives:

$$\Delta V_o = -\frac{\Delta Q}{\frac{C_1}{A} + \left(1 + \frac{1}{A}\right)\frac{S\varepsilon_0}{2d}} = -\frac{2\Delta Q d}{\frac{2C_1 d}{A} + \left(1 + \frac{1}{A}\right)S\varepsilon_0} \tag{3}$$

Assuming A>>1, (3) becomes:

$$\Delta V_o = d\frac{2\Delta Q}{S\varepsilon_0} \tag{4}$$

Consequently, by virtue of the negative feedback effected by capacitive coupling the output and input of inverting

amplifier 13 via the skin tissue, the variation in output voltage as a result of the charge step is directly proportional to the distance between armatures 23, 24 and the skin surface, in turn dependent on the three-dimensional structure of the skin.

With appropriate amplification levels (e.g. 1000-2000), it is possible to detect differences in capacitance of about ten fF and hence micrometric distances. The output signals of the device according to the invention are therefore such, when converted into grey levels, as to provide a highly reliable representation of the three-dimensional structure of the skin surface.

The advantages of the device according to the invention are as follows. In particular, as stated, it provides for a high degree of precision with no need for complex processing of the output signal; may be produced easily and integrated using current microelectronic technology; and is highly reliable, compact, and cheap to produce.

The device according to the invention may also be used to advantage in other applications requiring precise detection of small distances.

Moreover, the simple design of each cell enables a large number of cells to be accommodated in array structures for detecting two-dimensional physical quantities.

Clearly, changes may be made to the device as described and illustrated herein without, however, departing from the scope of the present invention. In particular, if fabrication techniques enabling the formation of elastic structures (micromachining techniques) are available, the electrode whose distance is being measured may be connected directly to the input or output of inverting amplifier 13 to eliminate one of armatures 23, 24. Moreover, all the components may be replaced by technical equivalents. For example, though an inverter such as inverting amplifier 13 is currently preferred for design and layout reasons, amplifier 13 may be implemented by any inverting or differential amplifier (e.g. an operational amplifier) in a charge amplifier configuration to increase the speed of the output signal.

Claims

1. A capacitive distance sensor (2) comprising a capacitive element (33, 34) presenting a first armature (23) which is positioned facing a second armature (18), said first and second armatures defining a distance (d) to be measured; characterized by amplifying means (13) defining an input (16) and an output (17); and in that said capacitive element (33, 34) is connected between said input and said output of said amplifying means, and forms a negative feedback branch.

2. A sensor as claimed in Claim 1, characterized in that said amplifying means comprises an inverting amplifier (13).

3. A sensor as claimed in Claim 1 or 2, characterized in that said capacitive element (33, 34) comprises a third armature (24) which is positioned facing said second armature (18); said first armature (23) being connected to said output (17) of said amplifying means (13); and said third armature (24) being connected to said input (16) of said amplifying means (13).

4. A sensor as claimed in any one of the foregoing claims, characterized by a layer of insulating material (25) contacting said first armature (23).

5. A sensor as claimed in any one of the foregoing Claims, characterized by logic means (7, 20) connected to said input (16) of said amplifying means (13) for generating an electric charge variation; and output detecting means (8) for detecting a voltage step at said output (17) of said amplifying means.

6. A sensor as claimed in Claim 5, characterized in that said logic means comprises a reference voltage source (12) for generating a voltage step; and a capacitive element (20) interposed between said voltage source and said input (16) of said amplifying means (13).

7. A sensor as claimed in any one of the foregoing Claims, characterized by a switching element (19) connected between said input (16) and said output (17) of said amplifying means (13).

8. A sensor device comprising an array (3) of distance detecting cells (2) connected to input enabling means (5, 6) and to output lines; characterized in that said cells (2) each comprise a capacitive distance sensor as claimed in one or more of the foregoing Claims from 1 to 4.

9. A sensor device as claimed in Claim 8, characterized by logic means (7, 20) connected to the inputs (16) of said amplifying means (13) for supplying said inputs with an electric charge variation; and output detecting means (8) for detecting a voltage step at the outputs (17) of said amplifying means.

10. A sensor device as claimed in Claim 9, characterized in that said logic means comprises reference voltage source means (12) and a number of capacitive elements (20); and in that each said distance detecting cell (2) presents a respective input (21) connected to said voltage source means (12) and to said input (16) of respective said amplifying means (13) via a said capacitive element (20).

11. A sensor device as claimed in Claim 10, characterized in that said enabling means comprises horizontal scanning means (5) and vertical scanning means (6); and in that said output lines are connected to an output buffer element (8).

12. A sensor device as claimed in Claim 11, characterized in that said voltage source means (12) comprises means for generating a reference voltage step supplied in parallel to said distance detecting cells (2); and in that said horizontal and vertical scanning means (5, 6) comprises means for sequentially enabling said distance detecting cells (2).

13. A method of detecting the distance between a first (23) and second (18) armature of a capacitive sensor (33, 34) as claimed in any one of the foregoing Claims from 1 to 7, characterized by the steps of: connecting said first armature (23) to a first terminal (17) of amplifying means (13), and said second armature (18) to a second terminal (16) of said amplifying means, so as to form a capacitive negative feedback branch of said amplifying means; applying an electric charge variation to an input (16) of said amplifying means; and detecting a voltage step at an output (17) of said amplifying means, said voltage step being directly proportional to a distance between said first and second armatures.

14. A method as claimed in Claim 13, characterized in that said step of applying an electric charge variation comprises the steps of: applying a first reference voltage to a capacitive element (20), and then applying, with a sharp variation, a second reference voltage other than said first reference voltage.

15. A method as claimed in Claim 14, characterized in that said step of applying an electric charge variation is preceded by an initializing step comprising the steps of closing a reset switch (19) connected between the input (16) and output (17) of said amplifying means (13), and then opening said reset switch.

16. A device for detecting fingerprints, comprising a capacitive sensor device (1); characterized in that said sensor device is formed as claimed in one or more of Claims 8 to 12.

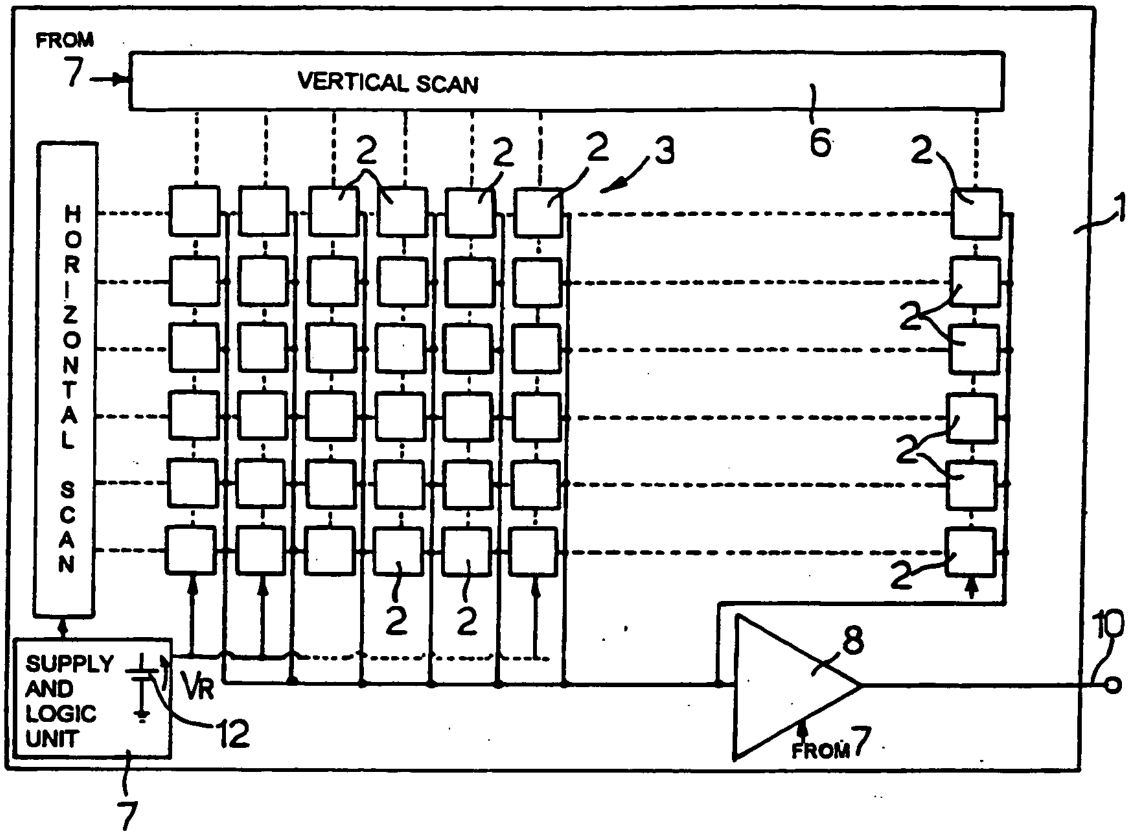

Fig.1

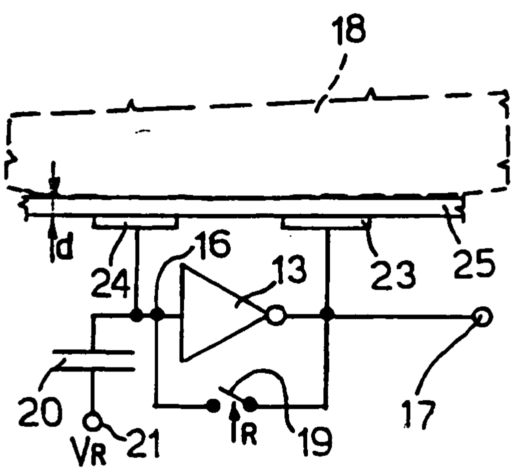

Fig. 2

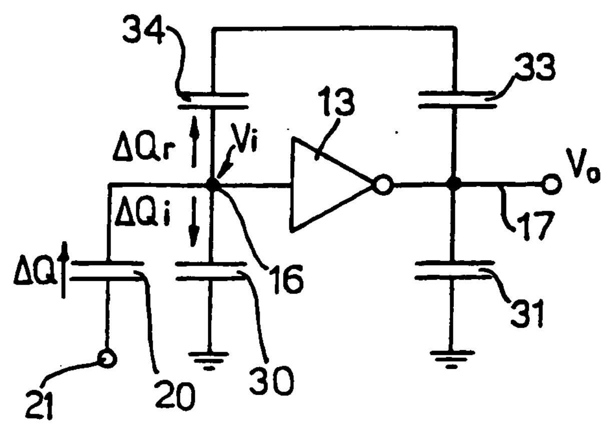

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 96 83 0068

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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Y		5,8,9, 11,16	
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A	* column 6, line 28 - column 7, line 3; figure 6 *	6,14	
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TECHNICAL FIELDS SEARCHED (Int.Cl.6)

G01B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	18 July 1996	Brock, T

CATEGORY OF CITED DOCUMENTS

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US-A-4 353 056 (TSIKOS CONSTANTINE) 5 October 1982 * the whole document * -----	1,8,13	
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